JPL

ENVIRONMENTAL TEST EFFECTIVENESS*

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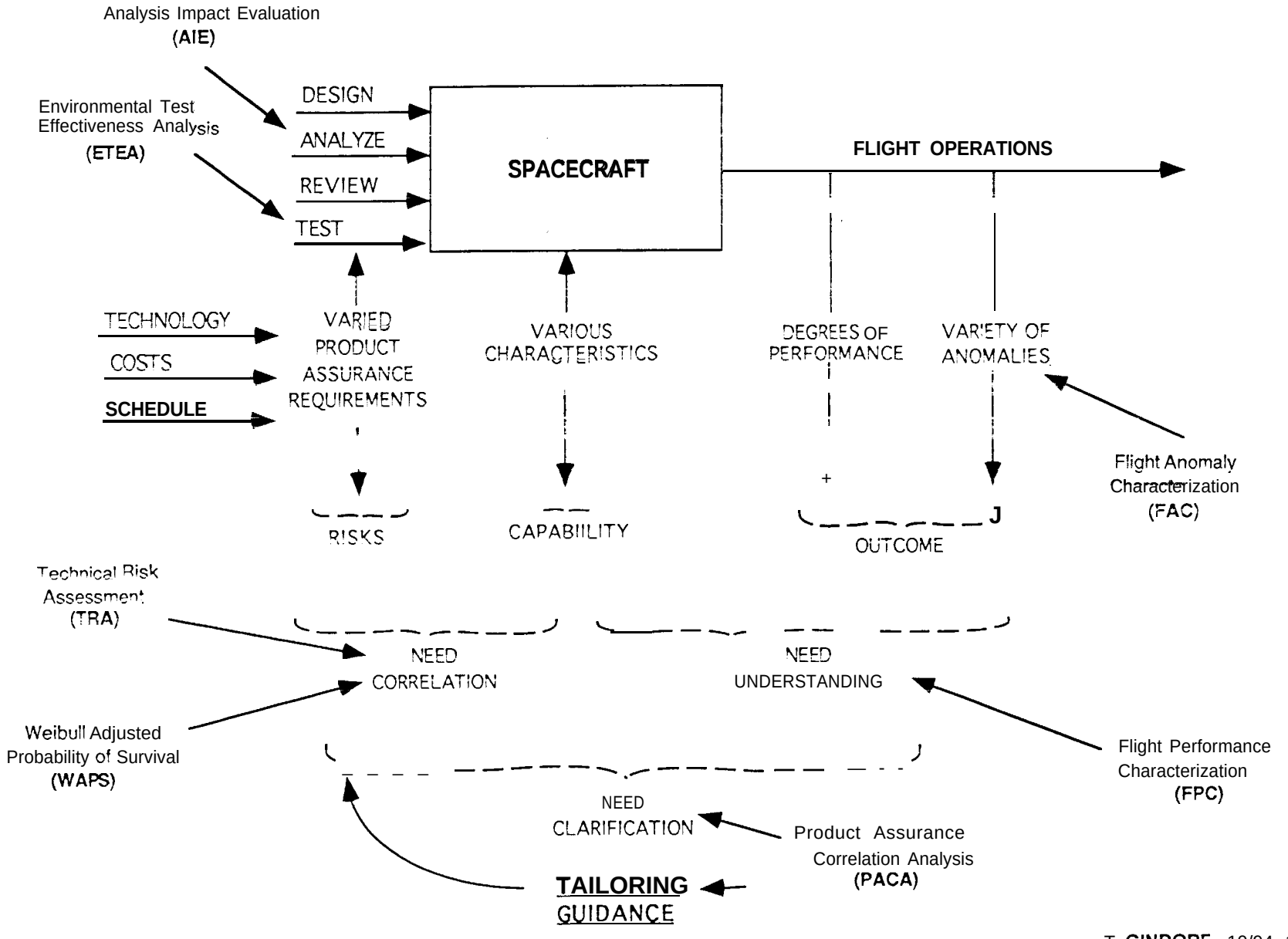
TAILORING AND TEST EFFECTIVENESS



JPL

TAILORING AND TEST EFFECTIVENESS

- NASA CODE Q SPONSORED EFFORT
- GOAL

  PROVIDE A TECHNICAL BASIS FOR TEST TAILORING TO IMPROVE TEST EFFECTIVENESS WITH FBC ORIENTATION

  - ESTABLISH A TEMPLATE FOR FURTHER ANALYSIS WHEN ADDITIONAL DATA IS AVAILABLE, e.g. SSED
- PAPER IS OVERVIEW OF EFFECTIVENESS REPORTS RELEASED TO DATE
- FULL REPORT -- LIVING DOCUMENT -- AVAILABLE AFTER SESSION

TETASTATUS

SIGNIFICANT TREND REPORTS RELEASED TO DATE

→	TETA-TO-0001 Rev A	POWERED-ON ASSEMBLY VIBRATION TESTING ON THE VOYAGER AND GALILEO PROGRAMS
	TETA-TO-0002	COMPARISON OF JPL PROCURED FLIGHT HARDWARE WITH *SYSTEM* CONTRACTOR PROCURED FLIGHT HARDWARE .
→	TETA-TO-0003	ENVIRONMENTAL TEST EFFECTIVENESS AS INDICATED BY VOYAGER AND GALILEO ANOMALIES
	TETA-TO-0004	COMPARISON OF VOYAGER AND GALILEO PROBLEM/FAILURES ON ELECTRICAL AND ELECTRONIC SUBSYSTEMS
→	TETA-TO-0005	EMC TESTING SIGNIFICANCE
→	TETA-TO-0006	EFFECTIVENESS OF GALILEO ASSEMBLY LEVEL DYNAMIC TESTS
	TETA-TO-0007	RELATIONSHIP OF DESIGN CHANGES AND WAIVED REQUIREMENTS TO DESIGN MATURITY
→	TETA-TO-0008	PROBLEM/FAILURE CAUSE
→	TETA-TO-0009	TEST EFFECTIVENESS AND RELIABILITY GROWTH IN JPL PROGRAMS
	TETA-TO-0010	CAUSES OF ANOMALIES DURING THERMAL-VACUUM TESTS
→	TETA-TO-0011	EFFECTIVENESS OF VACUUM ENVIRONMENT IN THE THERMAL-VACUUM TEST

TETA STATUS (Continued)

	TETA-TO-0012	ASSESSMENT OF EMI GROUNDING PROBLEMS ENCOUNTERED IN FLIGHT HARDWARE PROIR TO SYSTEM LEVEL EMI TESTS.
	TETA-TO-0013	IMPACT OF HARDWARE COMPLEXITY ON PROBLEM/FAILURES
	TETA-TO-0014	PROBLEM/FAILURE HISTORY VS. ORIGIN OF FLIGHT HARDWARE
	TETA-TO-0015	CLOSURE TIME FOR DESIGN RELATED PFRs
→	TETA-TO-0016	ADEQUACY OF PRELAUNCH TESTING BASED ON EARLY FLIGHT ANOMALIES
	TETA-TO-0017	CORRELATION OF ADVANCES IN SPACECRAFT DIGITAL TECHNOLOGY WITH EMC TEST FAILURE RATE
	TETA-TO-0018	TREND OF DEFECTS OBSERVED DURING GALILEO ASSEMBLY LEVEL DYNAMICS TESTS
→	TETA-TO-0019	EFFECTIVENESS OF GALILEO ASSEMBLY LEVEL DYNAMICS TEST VERSUS NUMBER OF AXES TESTED
	TETA-TO-0020	EMC TESTING FAILURES - WAIVERS VS. DESIGN CHANGES
	TETA-TO-0021	THE USE OF GROUND TESTING TO REDUCE POTENTIAL INFLIGHT ANOMALIES
	TETA-TO-0022	EMI ANOMALIES ENCOUNTERED PRIOR TO ACCEPTANCE TESTING

TETA-TO-0001, Rev. A

POWERED-ON ASSEMBLY VIBRATION TESTING ON THE VOYAGER AND GALILEO PROGRAMS

ISSUES

IS POWERED-ON VIBRATION NECESSARY/USEFUL.

Conclusion

POWER ON IS A NECESSARY CONDITION DURING VIBRATION TESTING TO UNCOVER ELECTRICAL PROBLEMS.

SIGNIFICANCE OF PROBLEM FAILURES UNCOVERED BY POWER-ON VIBRATION

	Voyager	Galileo
Total Vibration PFR's	84	20
Number of problems/failures attributed to power-on vibration which are not believed to be otherwise detectable.	44	14
Number of problems detected by powered-on vibration requiring redesign/rework and which if undetected would have had major mission impact.	3	1

SUMMARY OF POWER-ON VIBRATION RESULTS

	Voyager	Galileo
Percentage of Problems Requiring Powered-On Vibration for Detection	52% (44/84)	70% (14/20)
Percentage Of Detected Problems Which Have Major Mission Consequence In The Absence Of Redesign/Rework.	7% (3/44)	7% (1/14)

TETA-TO-0003

ENVIRONMENTAL TEST EFFECTIVENESS AS INDICATED BY VOYAGER AND GALILEO ANOMALIES

ISSUE

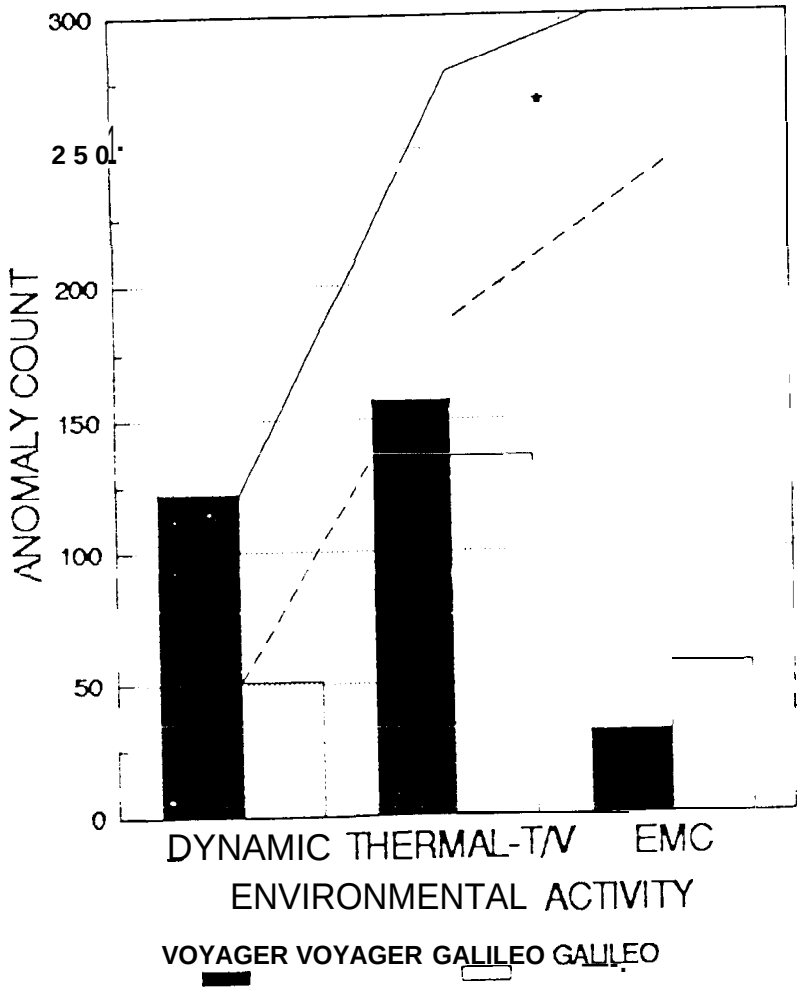
WHICH ENVIRONMENTAL TEST ARE MOST EFFECTIVE IN FINDING PROBLEMS?

CONCLUSIONS

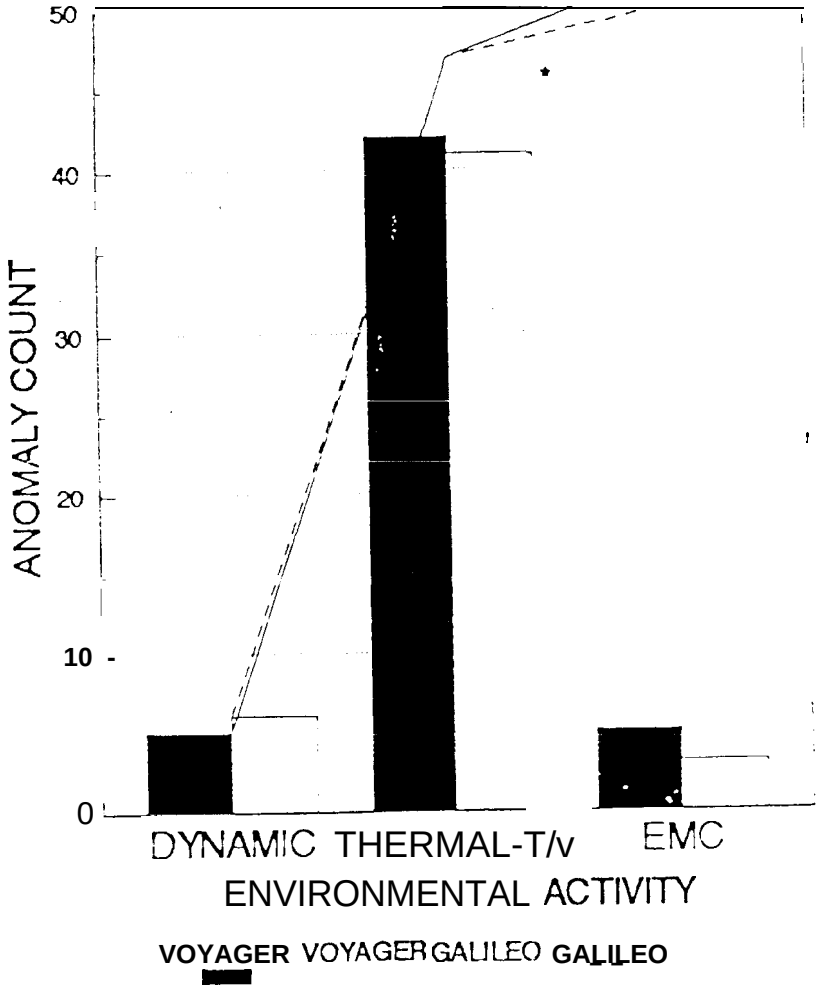
ON AVERAGE, THERMAL VACUUM TESTS ARE -200% MORE EFFECTIVE AT THE ASSEMBLY LEVEL AND -7500/0 MORE EFFECTIVE AT **THE SYSTEM LEVEL THAN VIBRATION TESTING. EMC TEST EFFECTIVNESS IS SIMILAR TO VIBRATION IN DETECTING PROBLEMS.**

	ASSY RATIO TN PFRS / VIB PFRS	SYSTEM RATIO TN PFRS / VIB PFRS
VOYAGER	1.3	8
GAULEO	3.0	7
AVERAGE	-2.1	-7.5

VOYAGER & GALILEO ASSEMBLY-EL ANOMALIES
VS TEST ENVIRONMENT



VOYAGER & GALILEO SYSTEM-LEVEL ANOMALIES
VS TEST ENVIRONMENT

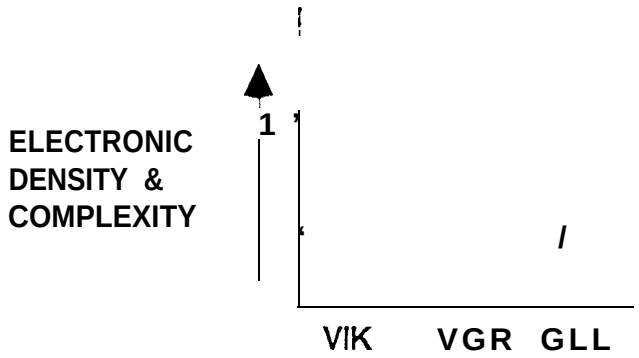


•LINES REPRESENT CUMULATIVE ANOMALIES AS TESTS PROGRESS

TETA-TO-0005

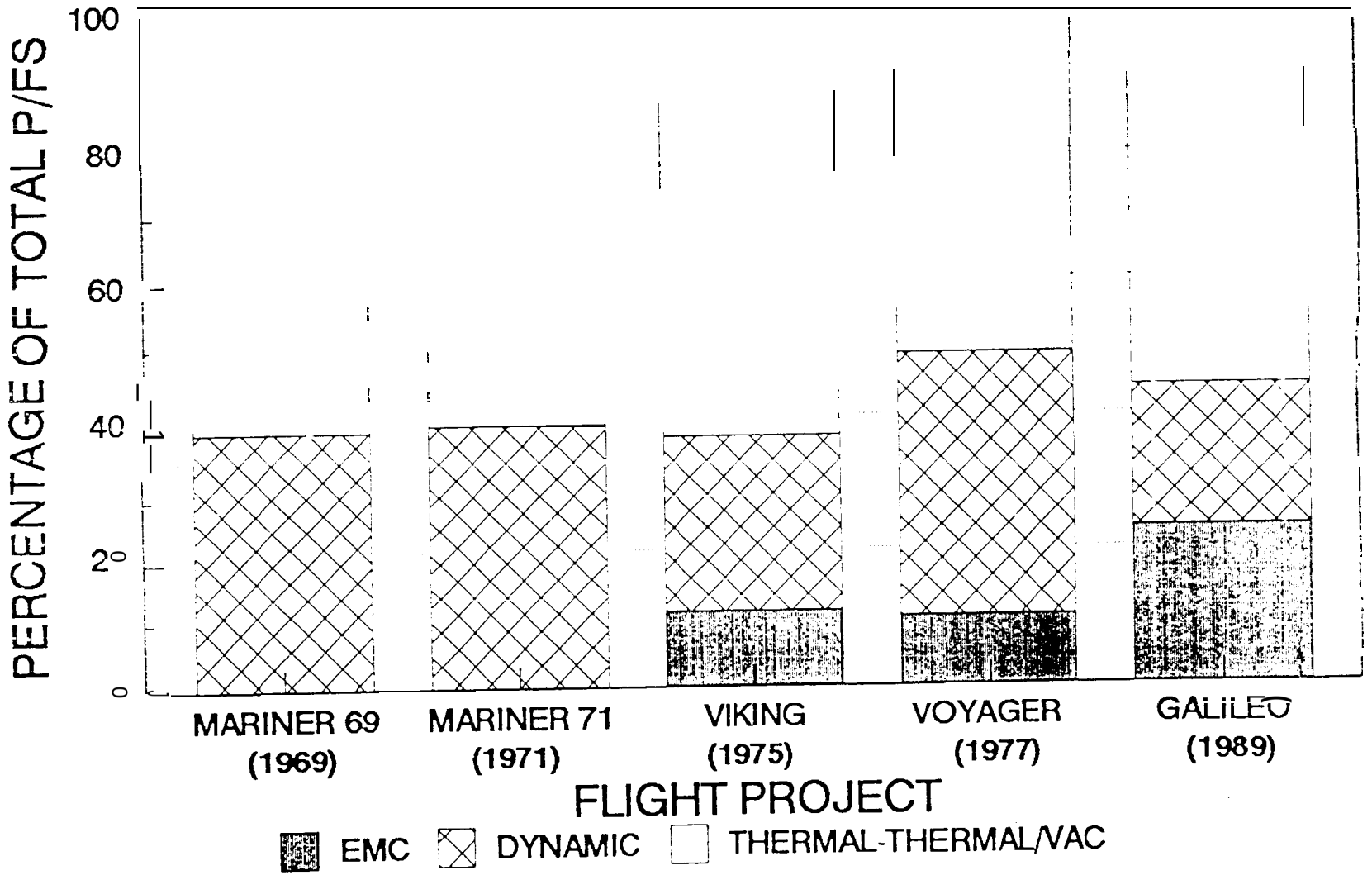
EMC TESTING SIGNIFICANCE

VIKING
VOYAGER
GALILEO



ASSEMBLY-LEVEL P/FS VS TEST ENVIRONMENT

BY PROJECT



TETA-TO-0006

EFFECTIVENESS OF GALILEO ASSEMBLY LEVEL DYNAMICS TESTING

ISSUES

WHICH DYNAMICS TESTING WAS MOST EFFECTIVE IN FINDING PROBLEMS?

CONCLUSIONS

SINE TESTING IS THE MOST PERCEPTIVE ASSEMBLY LEVEL DYNAMICS TEST*.

TOTAL GLL DYN TESTS	TOTAL PROBLEMS FAILURES	%0 SINE*	% RANDOM*	% ACOUSTIC	% SHOCK
252	66	~68%	~27%	~3%	~1.5%

QUAL		FA	
% SINE	% RANDOM	% SINE	% RANDOM
67%	25%	69%	31%

↑

MOST PERCEPTIVE AS WORKMANSHIP SCREEN

- SINE TEST CAN BE AN OVERTEST IF NOT CAREFULLY ADMINISTERED. EXCESSIVE CYCLES CAN BUILD AT RESONANT FREQUENCIES IN NON-FLIGHT MANNER.

*UNCERTAIN P/F (28) ARE PROPORTIONALLY DISTRIBUTED BETWEEN RANDOM AND SINE TESTS.

TABLE 2. DYNAMIC TEST FAILURES WITH DISTRIBUTED UNKNOWN TEST ENVIRONMENT

Test Env.	Total Tests			Failures			Yield	
	Quail PF	FA	Total	Quail PF	FA	Total	Relative To All Tests	Relative to Specific Env.
1. Random Vib.	66	46	112	10.4	7.7	18	7.1%	16.1%
2. Sine Vib.	66	46	112	27.6	17.3	45	17.9?/0	40.2%
3. Sine or Random	--	--	--	--	Dist	--	--	--
4. Shock	14	0	14	1		1	0.4%	7%
5. Acoustic	14	0	14	2	--	2	0.8%	14%
1 Total	160	92	252	41	25	66	26.2?/.	--

Table 2. provided below, was developed by distributing the failures attributed to "sine or random" vibration to each of the sine and random vibration environments porportionally.

TETA-TO-0008

PROBLEMFAILURE CAUSE

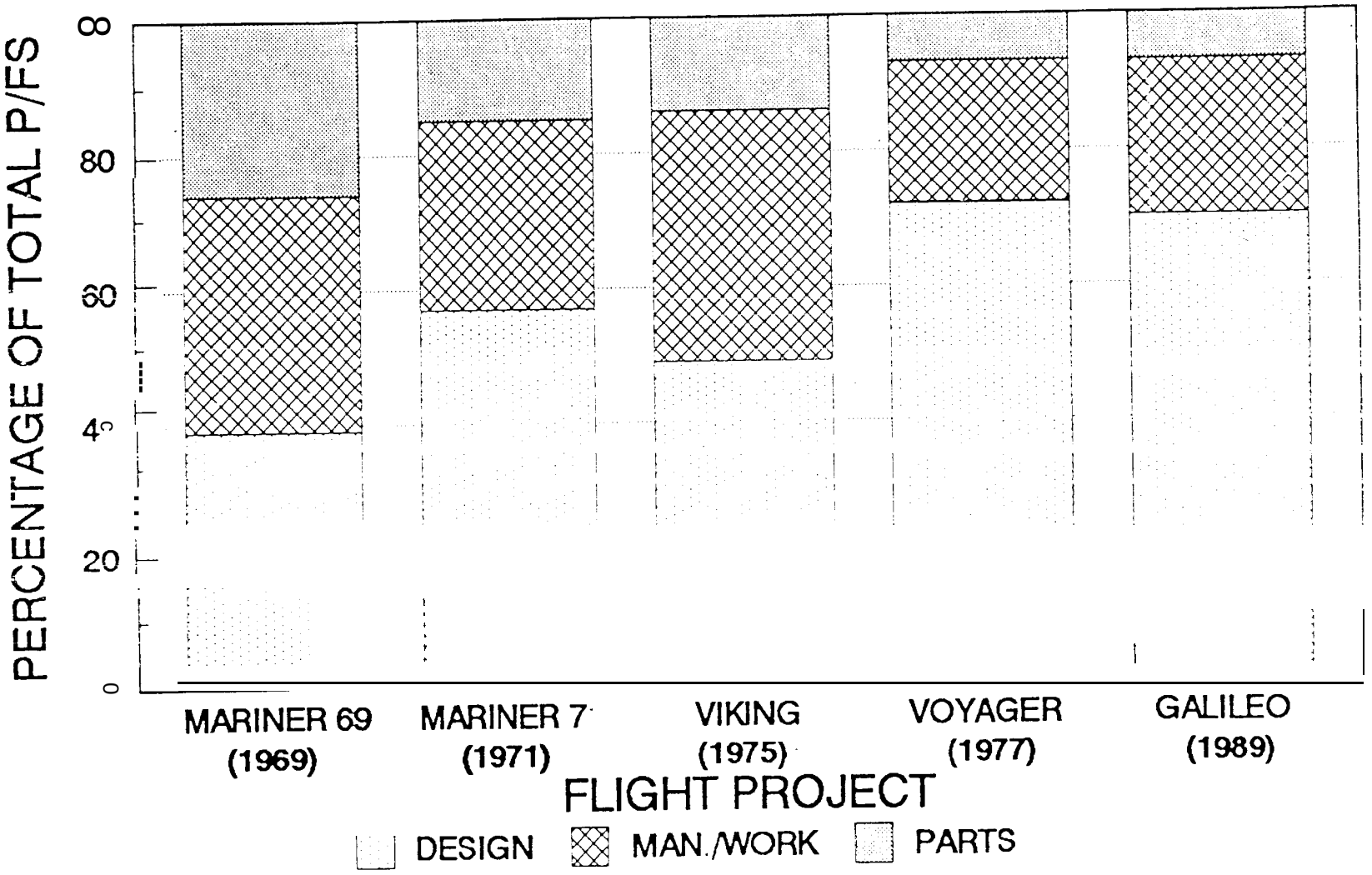
ISSUE

WHAT ARE THE PRINCIPAL CAUSES OF TEST PROBLEM/FAILURES ON JPL HARDWARE?

CONCLUSION

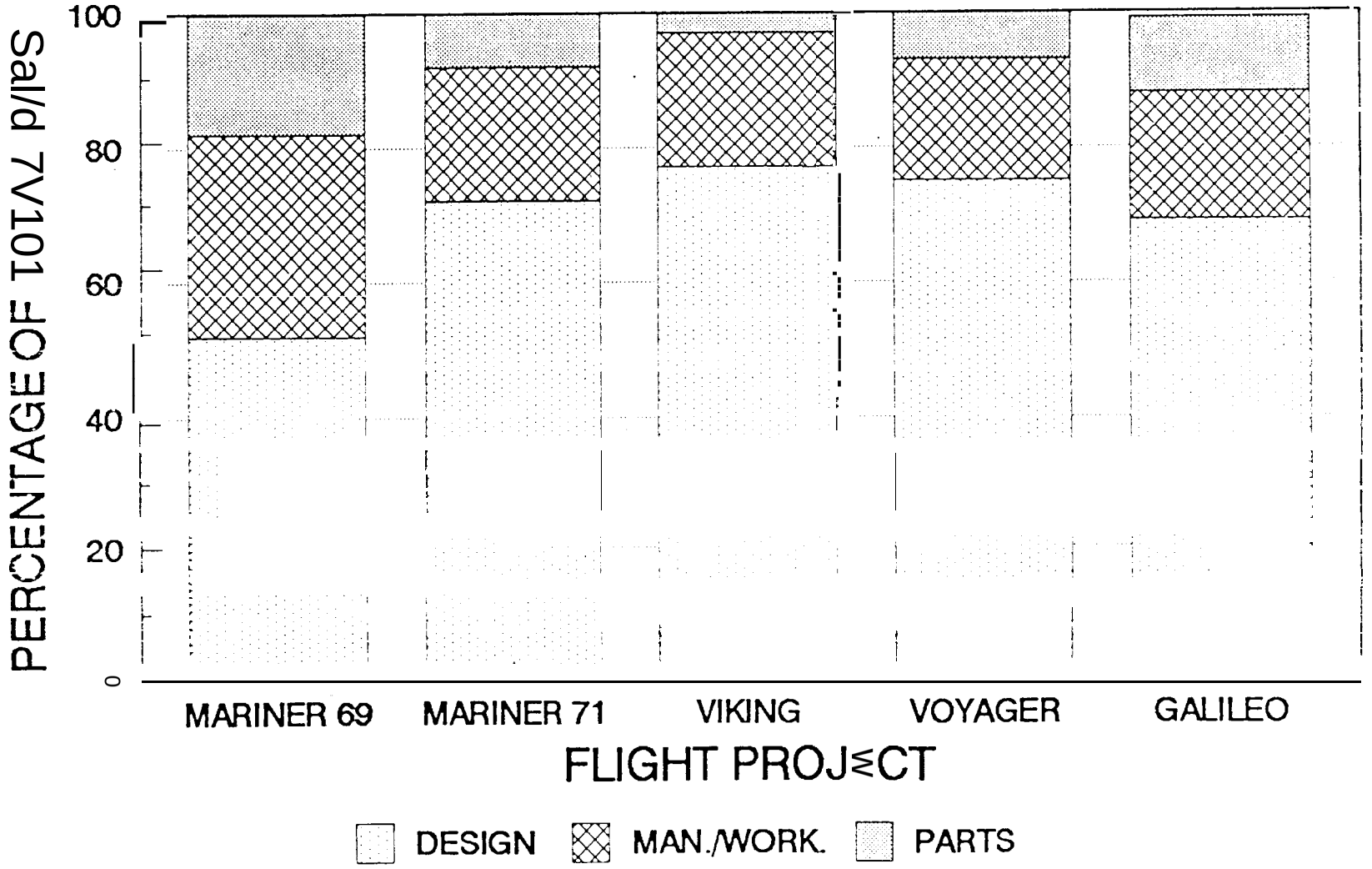
DESIGN PROBLEMS REPRESENT -600/0 OF THE PROBLEMSIFAILURES REVEALED DURING TESTING, WHILE PARTS RELATED PROBLEMS ARE THE CAUSE ~12% OF THE TIME. BY CONTRAST TO TIROS-NOAA, DESIGN CAUSES WERE ~32%, WHILE PARTS CAUSES WERE ~28% FOR S/C BUILT BY A MAJOR SYSTEM CONTRACTOR. MAY SUGGEST SIGNIFICANT DIFFERENCES IN THE PART PROGRAM.

ASSEMBLY-LEVEL P/FS BY CAUSE VS PROJECT



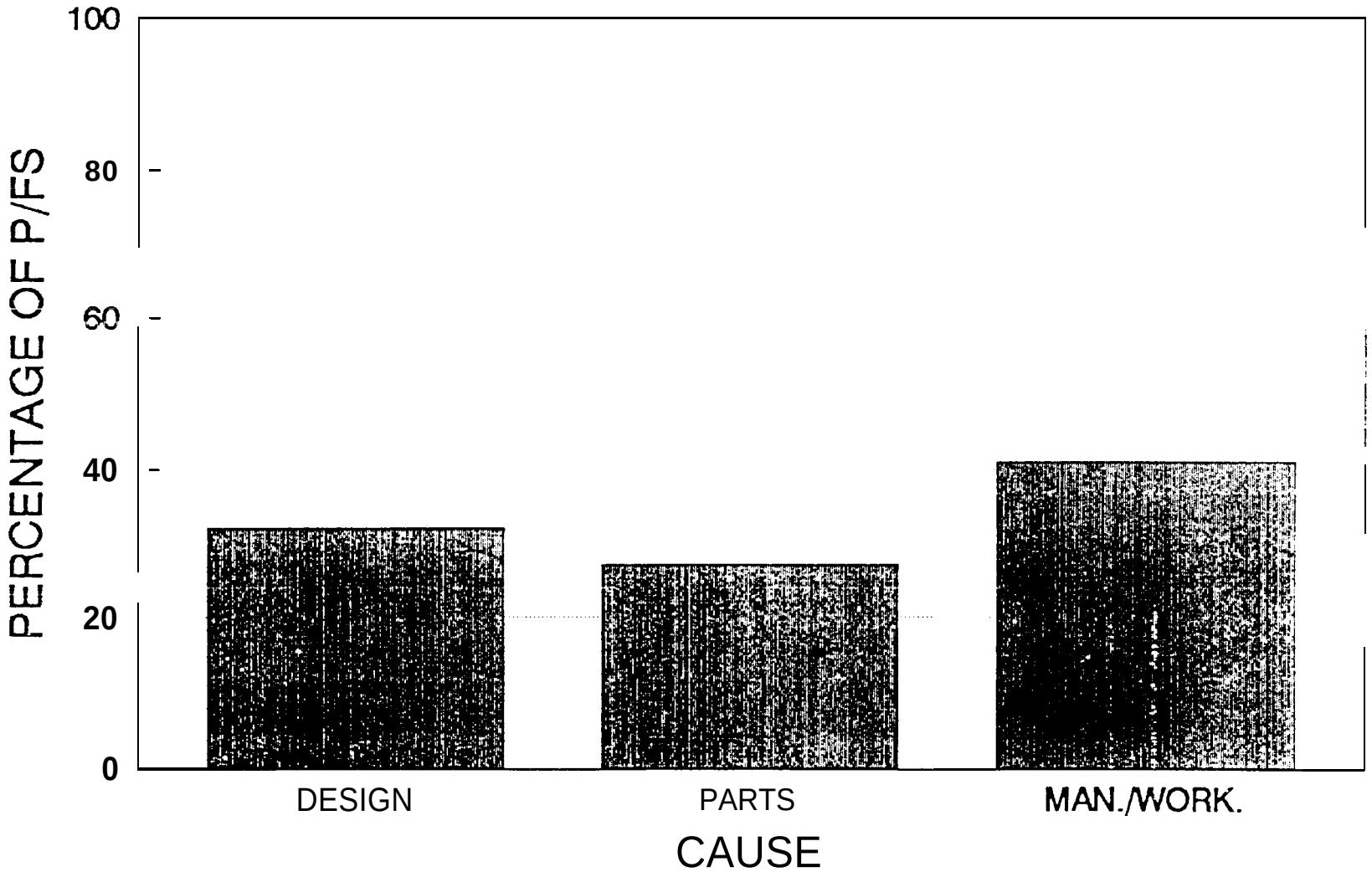
SYST≤M-LEVEL P/FS ∃Y C⊇USE

VS PROJECT



P/F CAUSES FOR TDR DATA BASE

BY PERCENT



TETA-TO-0009

TEST EFFECTIVENESS AND RELIABILITY GROWTH IN JPL PROGRAMS

ISSUE

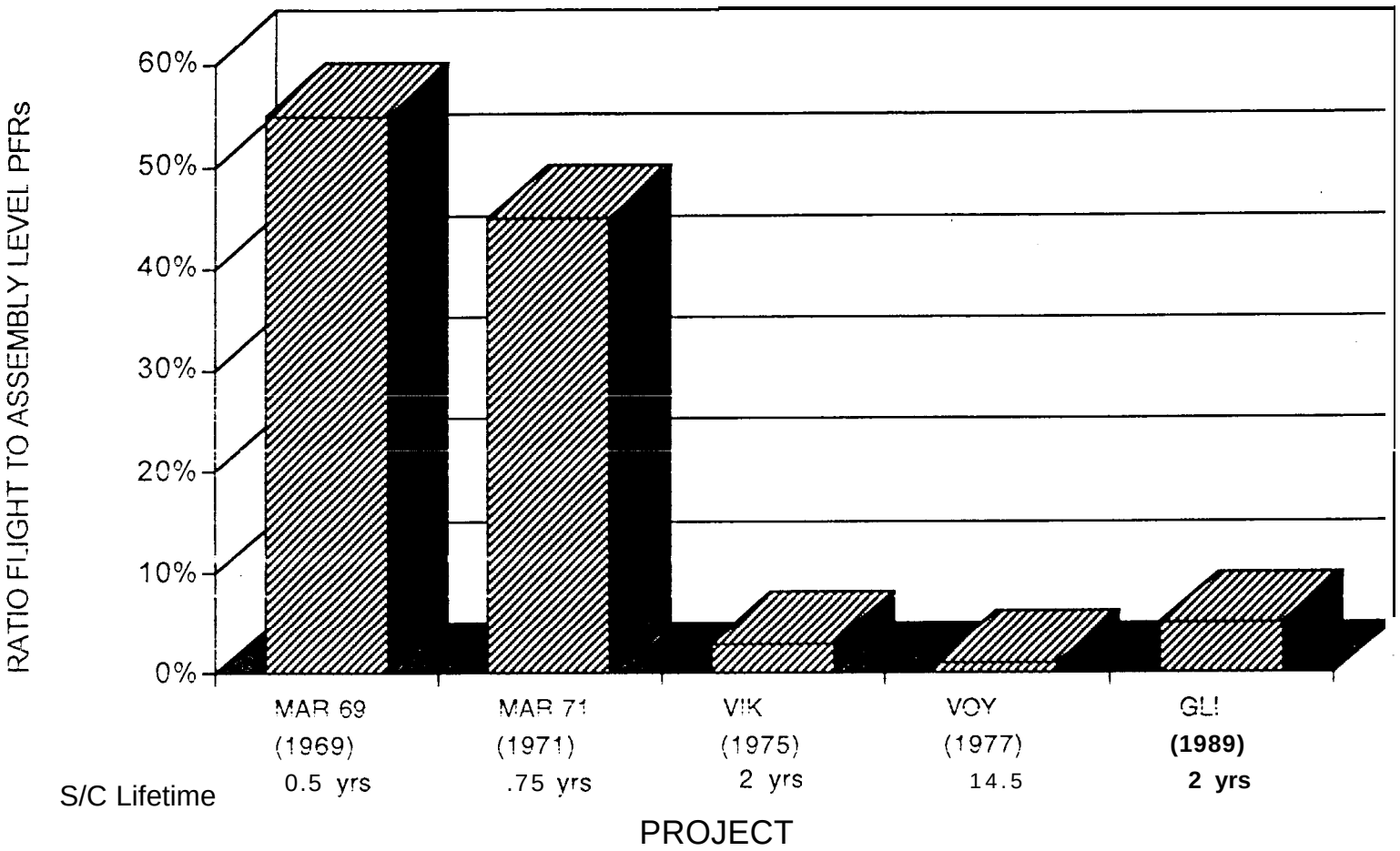
HAS ASSEMBLY TEST EFFECTIVENESS IMPROVED AND RELIABILITY GROWTH OCCURRED ON JPL PROGRAMS?

CONCLUSION

SIGNIFICANTLY IMPROVED ASSEMBLY TEST EFFECTIVENESS AND RELIABILITY GROWTH HAS OCCURRED OVER THE LAST 20 YEARS.

	RATIO OF FLIGHT PFRS TO ASSY PFRS
MARINER (1969)	~.55
MARINER (1971)	-.45
VIKING (1975)	-.03
VOYAGER ('1977)	-.02
GALILEO (1989)	-.05

Effectiveness of Test **Program and** Reliability Growth as **a Function Time**
(As of 4/1 5/92)



NOTE: ASSEMBLY = FA + QUAL

* Flight Anomalies normalized by S/C years

• Test Anomalies normalized by no. of hardware sets undergoing hardware testing

TETA-TO-0017

EFFECTIVENESS OF VACUUM ENVIRONMENT IN THE THERMAL-VACUUM TEST

ISSUE

IS VACUUM NECESSARY FOR A THERMAL TEST TO BE EFFECTIVE?

CONCLUSION

VACUUM DURING TESTING OF ELECTRONIC HARDWARE IS A SIGNIFICANT FACTOR IN THE EFFECTIVENESS OF THE THERMAL TEST BECAUSE THE RELATIONSHIP TO INDIVIDUAL PART /JUNCTION TEMPERATURES AND PERFORMANCE PARAMETERS.

A VACUUM ENVIRONMENT CAN ALSO BE A IMPORTANT FACTOR IN UNCOVERING PROBLEMS NOT INFLUENCED BY TEMPERATURE PER SE.

TABLE 1. ASSEMBLY-LEVEL TV TEST

PROGRAM	VOYAGER		GALILEO	
DEPENDENCY	NUMBER	PERCENT	NUMBER	PERCENT
Number where temperature only required	9	19.6	7	19.4
Number where temperature & vacuum both required due to influence of vacuum on temperature	10	21.7	17	47.2
Number where vacuum alone required	21	45.7	8	22.2
Number where dependency was undetermined	4.	8.7	3	8.3
Number where none of the specified environments was required.	2	4.3	1	2.8
TOTALS	46	100	36	100

TABLE 2. SYSTEM-LEVEL TV TEST

PROGRAM	VOYAGER		GALILEO	
DEPENDENCY	NUMBER	PERCENT	NUMBER	PERCENT
Number where temperature only required	0	0	4	10.3
Number where temperature & vacuum both required due to influence of vacuum on temperature	6	13	5	12.8
Number where vacuum alone required	29	63	14	35.9
Number where dependency was undetermined	2	4.3	2	5.1
Number where none of the specified environments was required.	9	19.6	14	35.9
TOTALS	46	100	39	100

TETA-TO-0016

ADEQUACY OF PRELAUNCH TESTING BASED ON **EARLY FLIGHT ANOMALIES**

ISSUE

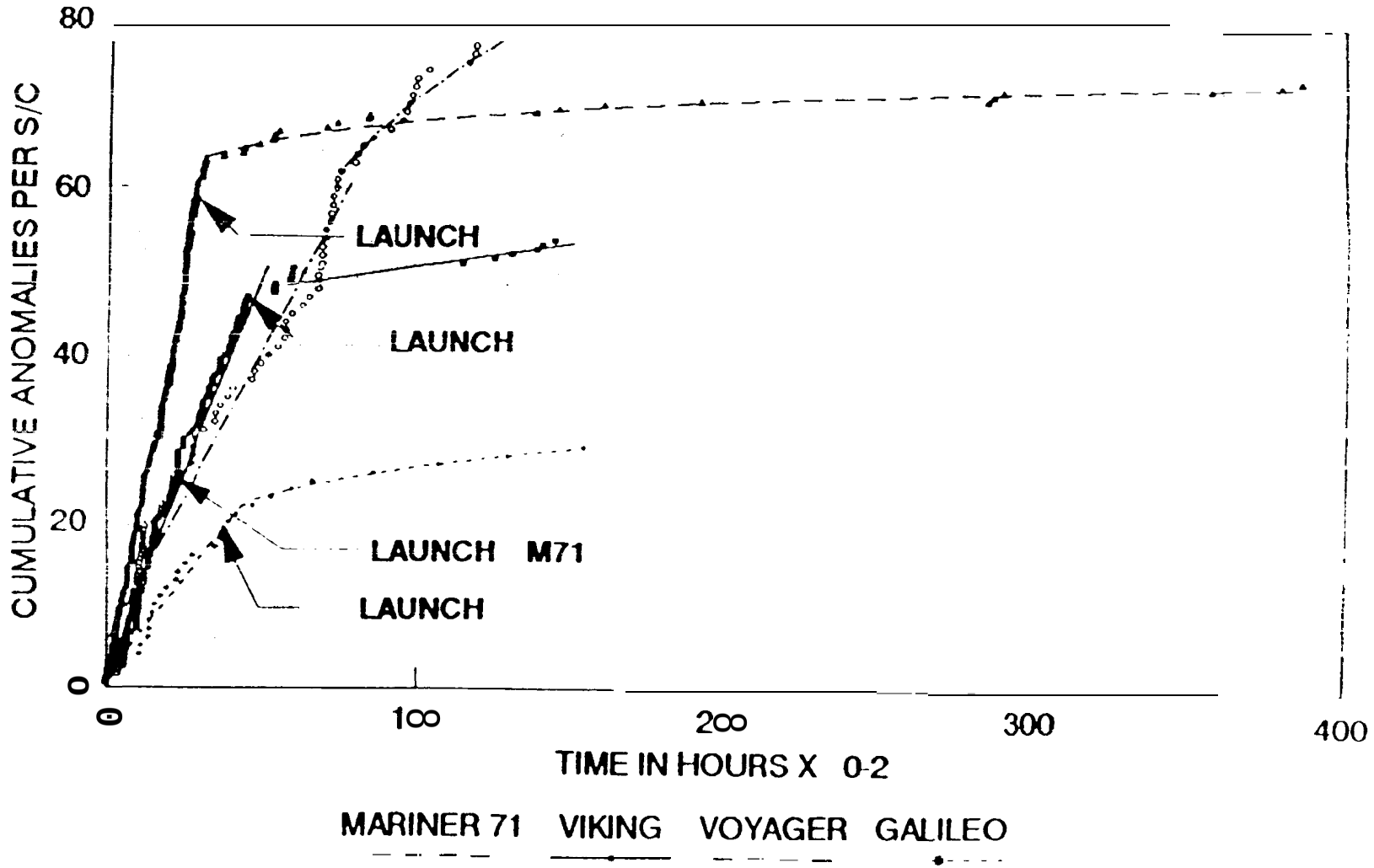
INFERENCE OF THE CORRELATION OF RATED PRELAUNCH PROBLEM/FAILURE TO THE RATE DURING THE EARLY PART OF S/C FLIGHT ON PRELAUNCH TEST ADEQUACY.

CONCLUSION

ON THREE OF FOUR JPL FLIGHT PROGRAMS THE INFLIGHT PROBLEM/FAILURE RATE IMMEDIATELY AFTER LAUNCH IS SIMILAR TO THE RATE DURING PRELAUNCH OPERATIONS. ADDITIONAL GROUND FUNCTIONAL TESTING WOULD LIKELY REDUCE EARLY FLIGHT PROBLEMS. HO

R≤G⊃ESSIO^ OF ⊃NOMALIES VS TIM≤

P≻≤ & POST LAUNCH



TETA-TO-0019

EFFECTIVENESS OF GALILEO ASSEMBLY LEVEL DYNAMICS TEST VERSUS NUMBER OF AXES TESTED

ISSUE

RELATIVE EFFECTIVENESS OF ASSEMBLY LEVEL DYNAMICS TESTS VERSUS THE NUMBER OF AXES TESTED?

CONCLUSION

BASED ON GALILEO EXPERIENCE, THE OPTIMUM REQUIRED NUMBER OF AXES IN WHICH ASSEMBLIES ARE VIBRATION TESTED TO DETECT POTENTIAL DESIGN/WORKMANSHIP DEFECTS IS TWO; LIMITING TESTING TO ONE AXIS WILL LEAVE MANY SUCH DEFECTS UNDETECTED. THREE AXIS VIBRATION APPEAR UNNECESSARY

TABLE 1 - DYNAMIC ASSEMBLY TEST FAILURES BY KNOWN ORDER OF OCCURENCE

Test Environment vs Type of Failure by Axis	Axis	Design	Workmanship	Manufacturing	Total
Sine Vibration	1st	3	1	0	4
	2nd	4	1	2	7
	3rd	0	0	0	0
Random Vibration	1st	1	0	0	1
	2nd	2	0	0	2
	3rd	0	0	0	0
Total		10	2	2	14

14 DESIGN, WORKMANSHIP, AND MANUFACTURING DEFECTS WERE DETECTED AFTER TWO AXES OF VIBRATION TESTING

5 WERE DETECTED AFTER THE FIRST AXIS OF VIBRATION

O WERE DETECTED AFTER DURING THE THIRD AXIS OF VIBRATION

***CARE SHOULD BE TAKEN TO SELECT THE MOST SENSITIVE AXIS.**